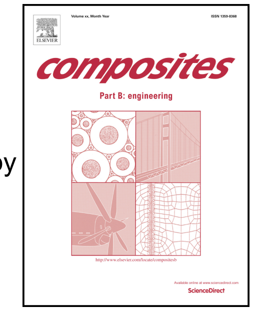

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Bending and free vibration of multilayered functionally graded doubly curved shells by an improved layerwise theory

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Abstract: An improved layerwise theory is established for the bending and vibration responses of multi-layered functionally graded doubly curved shells with material properties varying gradually and continuously across the whole shell thickness. The theory accounts for shear deformation and normal strain effects by assuming for each layer, a displacement field with zigzag first-order in-plane displacements and through-the-thickness parabolic transverse displacement. Moreover, it is assumed a stress field satisfying the loading conditions on the external shell faces and the continuity conditions of the internal stresses at the layers interfaces, so, there is no need for introducing in the present formulation any shear correction factor. For this purpose, a mixed variational statement is used. The continuity conditions for the displacements at the layers interfaces are used to decrease the degrees of freedom of the theory. Bending and free vibration problems are solved for FGM single- and three-layered sandwich open cylindrical and spherical shells with completely simply supported or clamped edges . Comparisons for some present results with numerical results obtained by other authors due to advanced 2D and 3D elasticity solutions are made showing the high efficiency of the present theory in predicting the bending and vibration parameters. Graphics are presented to demonstrate the importance of the normal strain effect for the static bending and free vibration of the considered shells.

Keywords: Layerwise theory; Mixed variational principle; Multilayered doubly curved shells; FMG core; Bending and vibrations.

1. Introduction

The concepts of the functionally graded materials (FGMs) was proposed by Japanese scientists in 1984 when they faced a challengeable problem of constructing a very thin thermal barrier with the capability to withstand a high difference in temperature on its two sides ranged from 2000 K to 1000 K through a 10 mm thickness [1]. Recently, these materials have a wide area of applications in all engineering and industrial fields such as aircraft and aerospace industry, the computer circuit industry, thermal-barrier structures and nuclear reactors. Many theoretical and numerical models are developed to simulate and analyze the mechanical and thermal behaviors of beams, plates and shells fabricated from these materials. Batra and Jin [2] modified a finite element method based on a first-order shear deformation theory to study the vibration response of FGM anisotropic rectangular plates with various edges conditions. Tornabene et al. [3] presented finite element techniques coupled with a refined two-dimensional (2D) differential quadrature method to analyze the free vibrations of sandwich cylindrical and spherical shells with FGM cores. Dongdong et al. [4] employed improved theory with four variables to study the thermo-mechanical behavior of FGM sandwich plates. Miguel and Reddy [5] utilized modified spectral/hp finite element method based on a seven-variable shell theory to carry out numerical simulations for the nonlinear response of FGM shells. Neves et al. [6] presented sinusoidal zigzag theories with thickness stretching effect to study the static buckling of FGM sandwich plates. Qu et al. [7] employed a first-order variational formulation coupled with a multi-segment partitioning technique to simulate and analyze various vibration responses of composite laminated shell structures with different boundary conditions and dynamic loadings. Pradyumna and Bandyopadhyay [8] modified the C0 finite element method by expressing higher-order theory with different transverse shear deformation modes in terms of Taylor's-series expansions to carry out vibration analysis for FGM shell panels. Fares et al. [9] presented a refined five-variable theory for the bending and vibrations of orthotropic FGM plates. Fares et al. [10] established a layerwise theory including thickness stretching effects to analyze the static bending of multi-layered FGM plates. Brischetto [11] established advanced 2D higher-order and layerwise models using mixed variational principle to analyze the bending response of several sandwich plates with a FGM cores. Several 2D theories of composite beams, plates and shells have been developed

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